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DESIGN OF AN ANALYTICAL SYSTEM FOR THE EVALUATION OF
GLOVES FOR PROTECTION OF PERSONNEL HANDLING XCSM

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ABSTRACT

To evaluate latex gloves for their resistance to XCSM penetration, a novel analysis system has been constructed. The objective of the system is to simulate the working environment of glove material used in a laboratory fume hood. The design of the sample cell provides for the secure placement of the test glove material between the exposure and sampling chambers, and provides for visual inspection of the material once placed in the cell to insure that the tension and positioning of the material does not compromise the testing process. The design also provides options such as control of sample temperature and airflow during the testing process. The flow rate of the air moving in the two chambers of the sample holder can be controlled independently between 0 and 125 linear feet per minute, matching most hood requirements. The sample exposure chamber will accommodate either a liquid or vapor challenge to the surface of the test material, while the use of positive sealing surfaces prevents contamination of the unexposed surface of the test material. The system incorporates on-line sample collection that is suitable for determining the short-term breakthrough anticipated for latex gloves. The sample collection system can concentrate, detect, and provide breakthrough data for GD, GB, HD and VX. The system can be used for gloves or other material up to 35-mil thick.

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INTRODUCTION

The use of protective gloves during the handling of CSM and XCSM is required for personal safety. Although the use of gloves tested for their resistance to CSM is required by USAMRDC Regulations 385-102 and 385-31, less is known regarding the resistance of gloves to XCSM. Questions have been raised recently concerning the XCSM permeability of different types of gloves. Frequent glove changing has been mandated for the safety of researchers, in part, due to the absence of specific permeation data for XCSM. In order to better define glove needs for XCSM work, the USAMRDC tasked the MREF to test various glove materials for XCSM permeation. In preparing for this, parameters needed to test the gloves were evaluated, along with the methods currently used to test glove material penetration by CSM. It was found that current methods used to test CSM penetration of glove materials relied on an apparatus unsuitable for properly evaluating some routinely used glove materials, such as latex, for XCSM permeation. In this paper, the design of an improved permeation cell system capable of testing both CSM and XCSM permeation through glove materials is presented.

DESIGN PARAMETERS

XCSM permeation differs from that of CSM because dilute XCSM, is by definition, at least 99% - 99.9% carrier solvent.⁽¹⁾ Schwoppe, et al.⁽²⁾, have demonstrated that, in similar solutions of pesticides, carrier solvents generally permeate first and at a much higher rate than the active ingredient, and the carrier solvents can significantly alter the permeation patterns of the active ingredient.⁽²⁾ Of the carrier solvents commonly in use for XCSM, both methylene chloride and hexane permeate 30 mil butyl gloves within 20 minutes of application, at rates exceeding 260 ug/cm²/minute, and cause significant degradation of the glove material within 30 minutes.⁽³⁾ To be realistic, therefore, any permeation test must mimic the effects of the carrier solvent and the dynamics of the XCSM mixture on the glove. The test should be designed to address one critical question: "Under specific use conditions, how long is a worker protected by a particular glove material when an undetected splash, spill, or contact with a given XCSM solution occurs?"

Since XCSM is composed of more than one ingredient, the individual components comprising a glove exposure in a laboratory hood would evaporate at different rates. This will cause the concentration of the XCSM to change with time. In fact, since most XCSM are made up in carrier solvents that are much more volatile than the CSM itself, with time, the carrier solvent will likely be depleted, leaving a film of neat CSM on the gloves. The changing nature of the CSM/carrier solvent mixture leads to a multiphasic permeation rate. At first, the permeation rate is affected primarily by the solvent. During this phase, the solvent may interact with the glove to

alter the permeability of the glove material to CSM, such as when chemicals degrade glove material. The second phase would be a period in which the concentration of CSM increases and eventually exceeds the concentration of the solvent. A final phase may include a period in which only neat CSM would be present to permeate. During the second and final stages, the carrier solvent/CSM mixture may have had lingering affects which continue to affect the permeation of CSM. Thus, the observed permeation of XCSM can have several permeation rate changes following exposure. This permeation pattern may be extremely different from the pattern observed using neat CSM. Therefore, a permeation system that does not mimic the evaporation rate dynamics of an XCSM exposure will not provide realistic information. The evaporation rate is, in turn, influenced by the temperature of the hand and the air velocity in the hood.

Controlling the temperature to approximate that of a hand not only affects the evaporation rate but also directly affects the rate of permeation. Perkins and You⁽⁴⁾ found that permeation of materials through butyl and other glove materials increased as the temperature increased at a rate predicted by the Arrhenius relationships. Temperature alone accounted for a halving of the breakthrough time in studies when the temperature was increased from 25° to 37°C.

Based on this information, the available test methods were evaluated to determine if the methodology to properly test XCSM permeation existed. It was found that the current industrial practice of performing protective clothing permeation evaluations was to use cells that conform to the standardized method that was first published by the American Society for Testing and Materials (ASTM) in 1985.⁽⁵⁾ The Army tests CSM permeation using methods first published as a Military Standard as early as 1952, with modifications in 1956 and 1974, and further modified in a CRDEC Special Publication dated 1984.⁽⁶⁾⁽⁷⁾ In designing the test for XCSM permeation, it was decided that the test should conform as closely as possible to the current military standard for CSM.

Initially, the current test systems were evaluated to determine if they could be used without modification. The first thing noted was that the permeation cells used did not provide temperature control, and provided air flow rates at variance with known hood air flow rates. Review of performance of the cells also revealed that leakage sometimes occurred during testing due to a shifting of the parts during the process of assembly which, in turn, led to leaks around the glove material. Once assembled, there is no way with the current permeation cells to verify that all of the components are properly placed. This has led to about a 10% "leaker" rate when testing glove materials. The primary problem introduced by the occasional "leaker" is that there is no way to determine whether leakage was caused by an improperly assembled cell or by permeation through a bad glove. Therefore, these data points are included with the others, resulting in significant skewing of the data, or data of such poor quality that retesting of the gloves is sometimes required.

Other areas of concern with the current cells include limited access to the glove surface area where the material is applied. The commercial cells often experience durability problems with cell components which are subjected to repeated use of CSM and decontaminants. Observed durability problems include: galling of threads, seizure of components, etc.

CELL DESIGN

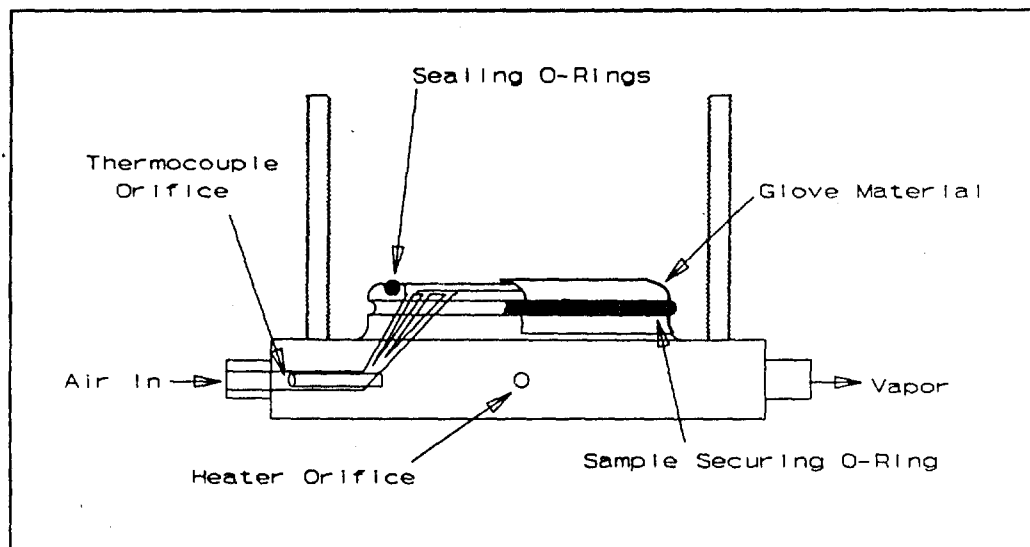


FIGURE 1. PERMEATION CELL BASE

To ensure that leakage in the new permeation cell is minimized, it is designed such that the glove material is secured in place with an O-Ring prior to completing the assembly of the cell (Figure 1). This O-Ring also allows tension to be maintained on the glove material, simulating actual wearing of the glove. Once secured in place, virtually the entire surface of the glove is still visible. To ensure consistency, grooves are milled into the cell body for all O-Rings for consistent seating and the O-Rings stay in place while the cell is being assembled. As further assurance, even after the permeation cell is fully assembled, the glove can be observed to ensure that it is in place (Figure 2). Another design feature ensures that should there be a leak, other than through the glove material itself, the leak would dissipate in the hood rather than be pulled into the analytical stream.

The void volumes of the cell chambers are such that when 1 liter per minute of air is passed through the upper chamber, the velocity across the wetted surface of the glove material is 100 linear feet per minute. This matches the current air flow requirements of XCSM/CSM hoods. The upper and lower chambers and air channels are constructed virtually identically so that when

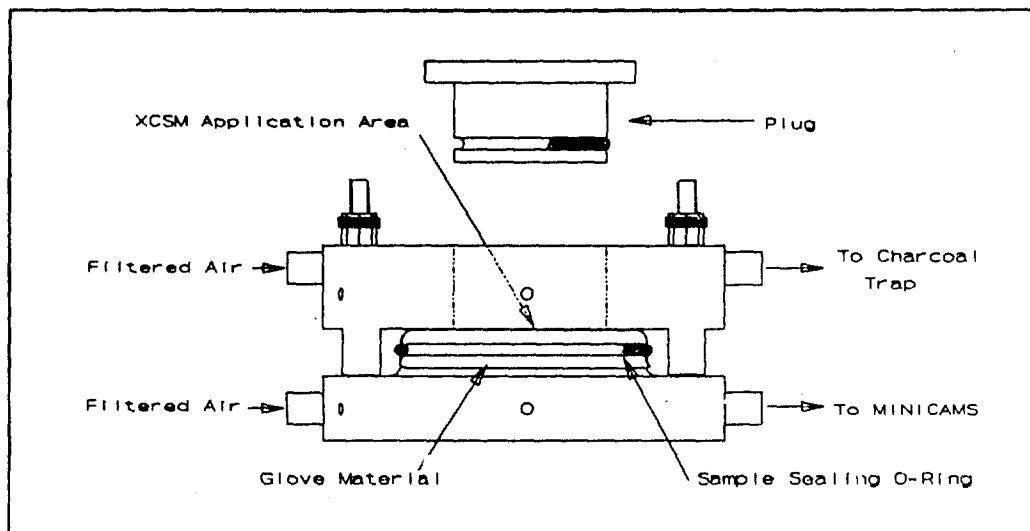


FIGURE 2. ASSEMBLED PERMEATION CELL READY FOR XCSM APPLICATION

equal flows are maintained, there is very little, if any, pressure differential across the glove material. The design also presents very little air flow restriction so that automated sampling equipment can function properly. A total air flow of one liter per minute was chosen because it is compatible with commonly used impinger, solid sorbent, and automated solid sorbent sampling methods currently in use.

The permeation cell has orifices on both the top and bottom portions suitable for the insertion of heaters and thermocouples. The heaters and thermocouples are connected to a feedback temperature controller to maintain the temperature of the cell. In our studies, the temperature is regulated at 94° F to simulate the average normal skin temperature of the human hand.

To facilitate application of material to the glove, the large removable top (Figure 2) exposes virtually all of the exposure surface of the glove material. This not only allows visual inspection of the glove surface, but also allows flexibility in the application of material on the glove. To prevent the problems caused by galling and seizing of the plug threads, the plug is designed to be pressed in place, sealing with an O-ring. The plug is easy to work with ergonomically, and the O-ring is disposable.

The permeation cell is constructed of stainless steel. Experience has shown that stainless steel is impervious to CSM, common solvents, and the common CSM decontamination materials. The O-Rings are made of Viton® and the cell was designed to accommodate commonly available sizes. Thus, the cells are reasonable enough in cost to be considered expendable.

APPLICATION OF THE PERMEATION CELL

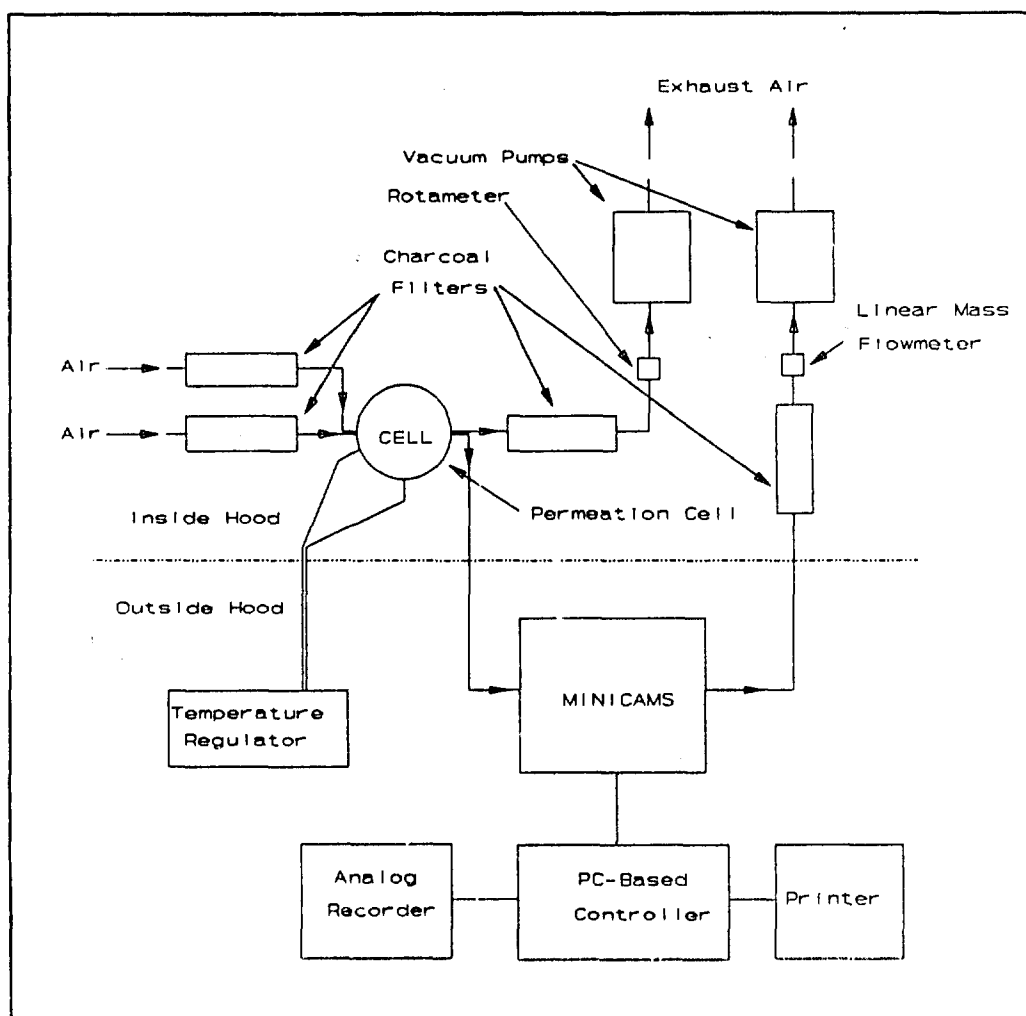


FIGURE 1. PERMEATION TEST SYSTEM

Permeation of CSM and of common solvents through latex gloves is known to be rapid (minutes), and thus one would expect that XCSM would permeate in a similar fashion. To be able to measure this permeation and derive a realistic breakthrough point, a method of analysis that provides frequent readings with the needed sensitivity and a small sample size is required. MINICAMS[®] provides the needed amount of data to prepare a profile of the permeation.⁽⁶⁾ The full system utilizing a MINICAMS[®] to evaluate the airstream on the permeation side of the glove is shown in Figure 3. Note

that the MINICAMS[®] is set up outside of the hood, with the vacuum pump placed within a XCSM or CSM certified hood. This assures that all lines outside the hood that carry the material are under negative pressure. The temperature controllers are placed outside the hood with connections to the thermocouples and heaters in the cell. The inlet air into the permeation cell is scrubbed with a charcoal trap, and air from the upper chamber is exhausted into the hood after passing through another charcoal trap. When the cell has been assembled with the glove material in place, the MINICAMS[®] is started and the temperature of the permeation cell is allowed to stabilize. This preliminary time also allows a period to ensure that there are no interfering peaks in the MINICAMS[®] window for the CSM being analyzed. To ensure that maximum information is obtained, the MINICAMS[®] is run with the software provided for evaluating permeation, and the system output is connected to a graph-chart plotter to capture the trace.

One hundred microliters of XCSM is applied on the glove material at a concentration within 10% of the maximum considered to be XCSM. This quantity completely covers the surface of the glove and allows realistic evaporation of the material. The cell design has proven to be quite versatile. Material as thin as one mil has been placed and retained in position without a support or backing. Material as thick as 35 mil has also been evaluated. The cell is easy to use and clean between tests. Cleanup is easily verified as the MINICAMS[®] begins sampling the cell before the run starts.

CONCLUSIONS

The permeation cell design presented has several advantages over previous designs. The cell is being used to test both single and multiple layers of gloves for their protective value against XCSM and, to date, no "leakers" due to improper sample positioning have been experienced. The resulting data produced using the permeation cell is more suitable for statistical analysis than that produced using the previously available cell designs. The enhancements in this design are expected to improve the quality of data obtained due to improvements in data collection and the use of more realistic operational temperatures. The greatest advantage of the cell, however, is that it is capable of addressing many of the unique parameters required to evaluate the permeation of a multi-component solution such as XCSM through glove material.

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